ERDC/CERL TR-13-16

Construction Engineering
Research Laboratory

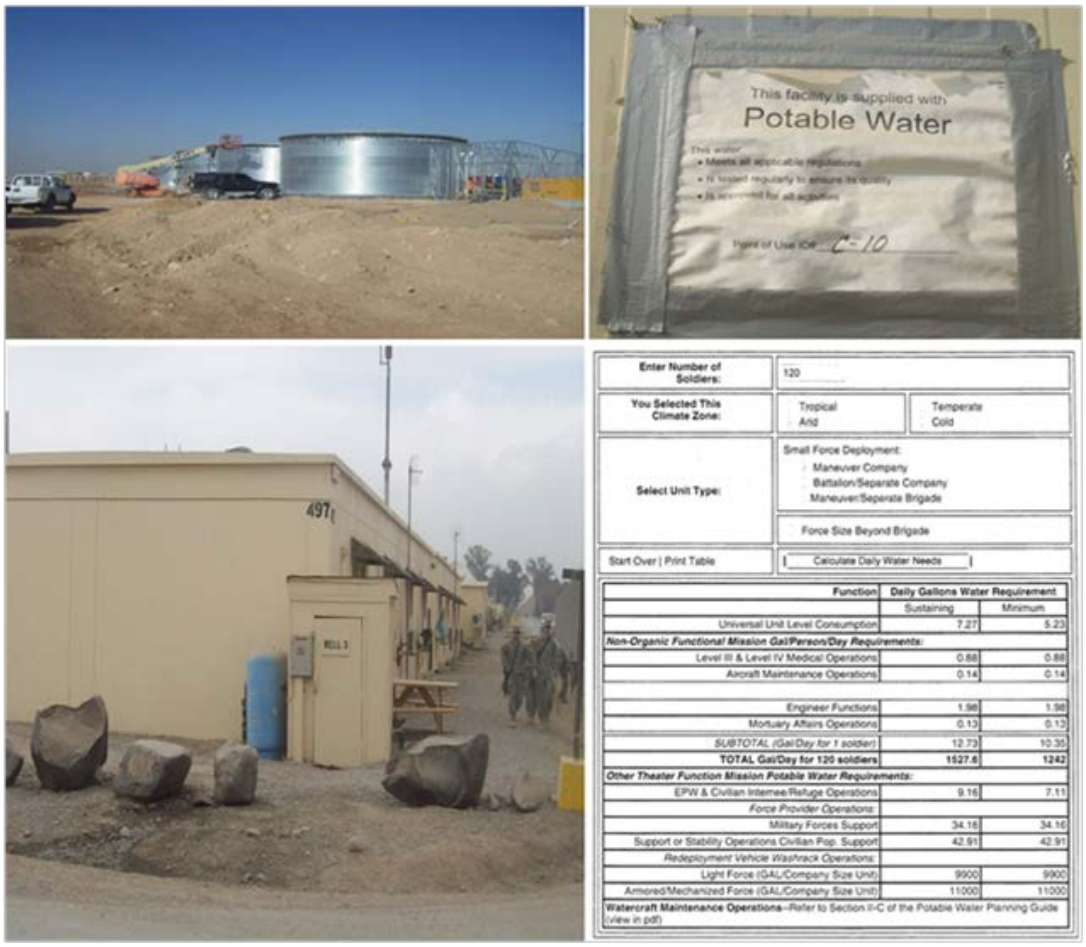
US Army Corps
of Engineers®
Engineer Research and
Development Center

ERDC
INNOVATIVE SOLUTIONS
for a safer, better world

Baseline Water Demand at Forward Operating Bases

H. Garth Anderson, Stephen W. Maloney, Kurt Kinnevan,
Edgar D. Smith, K. James Hay, and Gary L. Gerdes

September 2013



ERDC/CERL TR-13-16
September 2013

Baseline Water Demand at Forward Operating Bases

Stephen W. Maloney, Edgar D. Smith, K. James Hay,
Gary L. Gerdes, and H. Garth Anderson

Construction Engineering Research Laboratory (CERL)
US Army Engineer Research and Development Center
2902 Newmark Dr.
Champaign, IL 61822-1076

Final Report

Prepared for Headquarters, US Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 122G16

Abstract

Adequate supplies of potable water are essential for the establishment and operation of contingency base camps, especially in arid environments such as those in Southwest Asia. A baseline planning factor for water demand that reflects current contingency operations is essential to properly develop theater basing strategies and prepare valid base camp master plans. To provide that baseline, this work determined water usage at FOBs (13.3—34.4 gallons per capita per day [gpcd]), compared actual usage to planning factors previously developed by the Army, and estimated water requirements by base camp size (30 gpcd).

Table of Contents

List of Figures and Tables

Figures

Tables

Preface

This study was conducted for Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASAALT) under Project AMSCO 622784T4100, "Military Facilities Engineering Technology," Work Unit 122G16, "Forward Operating Bases." The technical monitor was John Munroe, US Army Natick RD&E Center, PM-FSS.

The work was managed and executed by the Environmental Processes Branch (CN-E) of the Environmental Processes Division (CN), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Mr. H. Garth Anderson. Deborah R. Curtin is Chief, CEERD-CN-E, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Alan B. Anderson, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the US Army Engineer Research and Development Center (ERDC), US Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Kevin J. Wilson, and the Director of ERDC is Dr. Jeffery P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
angstroms	0.1	nanometers
atmosphere (standard)	101.325	kilopascals
bars	100	kilopascals
British thermal units (International Table)	1,055.056	joules
centipoises	0.001	pascal seconds
centistokes	1.0 E-06	square meters per second
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (force) per square foot	95.76052	kilopascals
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (nuclear equivalent of TNT)	4.184 E+09	joules
tons (2000 pounds, mass)	907.1847	kilograms
tons (2000 pounds, mass) per square foot	9,764.856	kilograms per square meter
yards	0.9144	meters

1 Introduction

1.1 Background

Adequate supplies of potable water are essential for the establishment and operation of contingency base camps, especially in arid environments such as those in Southwest Asia. In future deployments to such locations, it is anticipated that security challenges will continue to become more varied and unpredictable, and that the range of operational settings within the spectrum of conflict will be considerably more complex—driving an expectation that US military assistance in civil support operations and stability operations will continue to rise. Moreover, current national strategies and Joint Operating Environment predict that long-term military commitments abroad will be expected to achieve national goals.

A baseline planning factor for water demand that reflects current contingency operations is essential to properly develop theater basing strategies and prepare valid base camp master plans. This work was undertaken to provide baseline water resource information pertaining to forward operating bases (FOBs) that can be used to optimize future deployed operations. The driving force behind this effort is the cost and risk associated with supplying water to FOBs in arid regions where sufficient water supply, particularly for personal consumption, is imperative. Since water usage in areas that have abundant water supplies must be considered separately from usage in areas that require all water to be delivered, this work differentiates —wherever possible— between water usage at FOBs that rely on water delivery and usage at FOBs that use local supplies, to ensure that locations with an availability of ample water do not skew water data to the higher end of usage.

1.1 Objectives

The objectives of this study were to:

1. Determine water usage
2. Compare actual usage to planning factors previously developed by the Army
3. Provide baseline water resource information pertaining to FOBs that can be used to optimize future deployed operations.

1.2 Approach

The objectives of this work were met in the following steps:

1. The study team reviewed current Army doctrine as well as openly a literature on water resource requirements for arid regions.
2. Published information was compared to previous lessons learned on water management from Bright Star Exercises conducted during the 1980s.
3. Researchers contacted personnel deployed in theater, primarily by e-mail and telephone, to determine availability of water usage data specific to forward operating bases.
4. Relevant field operating data were also locate using searches of the secure Internet system, Secret Internet Protocol Router [SIPR] Network (SIPRNET).
5. Construction Engineering Research Laboratory (CERL) researchers visited Camp Atterbury and the National Training Center at Fort Irwin, CA, to collect information on water use at training FOBs.
6. An Army Reserve Officer, on loan to CERL to support the study, visited seven contingency base camps in Afghanistan in January 2011 to interview base camp personnel and collect data from logistical support contractors.
7. Results of this research were compiled and analyzed to determine baseline water resource information pertaining to FOBs.

1.3 Mode of technology transfer

It is anticipated that the results of this study will inform and support:

- several Major Objectives of the 2008 Army Campaign Plan as outlined in the 18 June 2008 Execution Order (EXORD) (HQDA 2008)
- the current Base Camp Integrated Capabilities Development Team (ICDT) assessments that the US Army Maneuver Support Center (MANSCEN) are performing for the US Army Training and Doctrine Command (TRADOC)
- the development of interoperable systems across the US Department of Defense (DOD).

This report will be made accessible through the World Wide Web (WWW) at URLs: http://www.cecer.army.mil and http://libweb.erdc.usace.army.mil

1.4 Terms and definitions

The following definitions, terms, and sizes for base camps were used for this study.

1.1.1 Base camp definition

The TRADOC Base Camp Functional Area Analysis (TRADOC 2009) defines a "base camps" as:

> ... an evolving military facility that supports the military operations of a deployed unit and provides the necessary support and services for sustained operations. Base camps consist of intermediate staging bases and forward operations bases and support the tenants and equipment. While base camps are not permanent bases or installations, they develop many of the same functions and facilities the longer they exist. A base or base camp can contain one or more units from one or more Services. It has a defined perimeter and established access controls and takes advantage of natural and man-made features.

1.1.2 Base camp terminology

This study assumes that the term "base camp" applies to all contingency base locations, and is therefore equivalent to other such designations as: Forward Operating Base, Combat Outpost, Contingency Operating Location, Firebase, and any other terms used in the current theater.

1.1.3 Base camp sizes

The study uses three standard base camp sizes, based on military population only. It should be understood that base camps will also support a sizable civilian and contactor population, often equaling or exceeding the military population:

- Brigade: 6000 soldiers
- Battalion: 1000 soldiers
- Company: 150 soldiers.

2 Planning Factors for Water Supply

A number of planning factors for water supply are available to the theater level basing planner or base camp master planner. While some are fairly detailed and account for the mission, activities, and climate, others are more general per capita estimates.

2.1 CASCOM water planning tool

Planning factors have been developed over a number of years. Current doctrine can be found in the "AGC Geospatial Center Water Consumption Calculator,"* a convenient tool developed by the Combined Arms Support Command (CASCOM), the US Army's Sustainment Center of Excellence. In this web based tool, the user selects a location on a map and the unit size, after which the tool calculates water requirements.

The Water Consumption Calculator operates through a secure Internet connection that requires a Common Access Card (CAC) to sign on. Once the tool is opened, a map of the world is presented from which the region is selected using a mouse click. The tool requires the user to specify only a number of personnel and type of unit (from three choices) to calculate water requirements. Figure 1 shows a typical output for the projected water requirements for a company outpost (COP) of 120 personnel (PAX) in the format that the computer tool generates. This tool generates a basic sustaining requirement of approximately 13 gpcd. Given that the current mission in Afghanistan generally falls under the "Military Forces Support" function, demand increases to 34 gpcd. This accounts for additional base camp functions such as showers, laundry, and dining facility (DFAC).

2.2 Factors derived from Bright Star exercises

The US military conducted several exercises of desert warfare in the 1980s designated "Bright Star." As part of the exercise, water management and water operations were closely monitored. The purpose of the water management team at these exercises was to observe water use and water conservation/waste. Nonetheless, the observed rate of use at the area designated as Cairo West was 13 gpcd at Bright Star 83 (Bandy et al. 1984).

* Available through URL: https://tsunami.tec.army.mil/externalpages/water/calc/Global.htm

Enter Number of Soldiers:	120
You Selected This Climate Zone:	Tropical / Arid / Temperate / Cold
Select Unit Type:	Small Force Deployment: Maneuver Company / Battalion/Separate Company / Maneuver/Separate Brigade; Force Size Beyond Brigade
Start Over | Print Table	Calculate Daily Water Needs

Function	Daily Gallons Water Requirement	
	Sustaining	Minimum
Universal Unit Level Consumption	7.27	5.23
Non-Organic Functional Mission Gal/Person/Day Requirements:		
Level III & Level IV Medical Operations	0.88	0.88
Aircraft Maintenance Operations	0.14	0.14
Engineer Functions	1.98	1.98
Mortuary Affairs Operations	0.13	0.13
SUBTOTAL (Gal/Day for 1 soldier)	12.73	10.35
TOTAL Gal/Day for 120 soldiers	**1527.6**	**1242**
Other Theater Function Mission Potable Water Requirements:		
EPW & Civilian Internee/Refuge Operations	9.16	7.11
Force Provider Operations:		
Military Forces Support	34.16	34.16
Support or Stability Operations Civilian Pop. Support	42.91	42.91
Redeployment Vehicle Washrack Operations:		
Light Force (GAL/Company Size Unit)	9900	9900
Armored/Mechanized Force (GAL/Company Size Unit)	11000	11000
Watercraft Maintenance Operations--Refer to Section II-C of the Potable Water Planning Guide (view in pdf)		

Figure 1. Output of CASCOM Water Planning Tool.

Similarly, during Bright Star 85, peak water production at Cairo West was 100 Kgal/day, supporting a peak population of 7500 (Murphy et al. 1987). This also calculates to approximately 13 gpcd. The usage at Bright Star exercises was not constrained by supply convoys, and did not represent contingency operations with long durations. Water was readily available from a well at Cairo West, which lessened the need to conserve.

2.3 World Health Organization

The World Health Organization (WHO) has also developed planning factors for water use. The availability of clean potable water is a major concern in the developing world, and WHO has dedicated much effort to determining minimal sustainment requirements. WHO guidelines consider many options, and the availability of water weighs heavily on the usage. However, they recommend 50 liters per capita-day (13.2 gpcd) as a basic human right (Gleick 1996). This would meet the minimal needs of sustainment based on their analysis. This is very close to 13 gpcd as recommended by CASCOM.

2.4 Force provider

The US Army has developed an equipment set called Force Provider (Ouellette 2008), which is designed to provide a complete base camp to include showers, latrines, laundry, and DFAC. The design capacities vary by camp size, but the smallest unit is design for 550 personnel, with the provision for a daily water use of 25,000 gal. This results in a per capita daily production capacity of 45 gal. That compares well to the maximum usage of 43 gpcd (see Figure 1), and indicates that the Force Provider base camp should be capable of meeting CASCOM requirements, even at the maximum daily use estimated.

2.5 LOGCAP planning

The Logistics Civil Augmentation Program (LOGCAP) provides logistical support and services to contingency facilities world-wide through several large contractors. One contractor, Kellogg, Brown, and Root (KBR), used a minimum planning factor of 18.4 gpcd (Wagstaff 2009), substantially greater than the CASCOM factor of 13 gpcd. In addition to the higher minimum, KBR used a planning factor of 50 gpcd when including DFAC, ice, laundry, and washrack operations. Another briefing (3rd Army 2009) also cited a planning factor of 50 gpcd.

2.6 Afghanistan master plans

In Afghanistan, US Air Force Expeditionary Prime Base Engineer Emergency Forces (BEEF) Squadrons (EPBS) prepare all base master plans under the guidance of US Forces-Afghanistan (USFOR-A). Master plans produced in 2010-11 use a water supply planning factor of 20 gpcd, which includes showers, latrines, laundry, and dining facilities (877th EPBS 2010).

2.7 Comparison of planning factors

A comparison of the above planning factors shows that the basic individual soldier sustainment level of 13 gpcd appears to be consistent with both previous DOD doctrine and WHO guidelines. However, considering major factors such as laundry, dining facilities, and washracks, the planning factor can increase significantly. Both CASCOM and WHO recommend higher water usage depending on level of infrastructure and development. Both KBR and the US Air Force PRIME BEEF consider additional base camp functions such as laundry and DFAC, which reflect higher planning factors (Table 1).

Table 1. Water Demand planning factors (gpcd).

Basic Sustainment			Sustainment with Additional Functions		
CASCOM	WHO	Bright Star	KBR	EPBS	CASCOM
13.0	13.2	13.0	18.4	20.0	34.1

3 Data Derived from the Field

The Secret Internet Protocol Router Network (SIPRNet) is the secure computer environment used by the Department of Defense to transmit classified information. Searches were conducted via access to the SIPRNet to find documents with relevant water usage field data. Most searches were done within the Army Knowledge Online SIPRNet (AKO-S) site. Additional sites searched included Army Forces Central Command (ARCENT), intelink.sgov.gov, and the Battle Command Knowledge System.

A list of keywords developed to perform basic keyword searches revealed clues about the military language used in documents related to water. For example, "Class I" is a more productive search term than "potable water." Other examples of successful search terms include: Concept of Support, Quartermaster, LOGCAP, and BTW (bottled water). The keywords and their multiple combinations were used to generate lists of relevant documents that were viewed for water usage data. Many documents were either unavailable and required registration (permission) to review. Considering the number of these documents and the uncertainty of their relevance, it was not feasible to request such permissions; therefore this review considered only available documents.

Determining the actual water usage at base camps requires knowledge of total water delivered and number of personnel at the location. Much of the existing data on water usage in Iraq and Afghanistan come from Army logistics reports. These reports indicated the quantity of water produced, but do not indicate quantities shipped to specific locations, or number of personnel receiving the water supplies. For example, Catanese and Ford (2005) reported on supplying water to the 1st Infantry Division during a 1-year period in Iraq. The water supplied included 3.3 million gal of bulk water, and 822,000 bottles of water. The source of the water was not identified. Ketchum (2007) reports on production of 5 million gal of water in just 3 weeks using a canal that branched off the Tigris River. Neither report indicated how many personnel were supplied.

Field data from a non-arid region at the Camp Bulwark FOB (in Bulgaria) indicate water usage of 20 gpcd (Buchart Horn Gmbh 2004). Camp Bul-

wark was a short term FOB that had a life-span of approximately 5 months. The figure of 20 gpcd was based on water usage over 3 weeks, from 31 July 2004 to 14 August 2004, when the FOB achieved its maximum capacity of 1100 PAX. During that time, average water use was calculated at 155,000 gal (586,675 L) per week, or approximately 20 gpcd (Buchart Horn Gmbh 2004, Table 4.2).

Kinnevan (2008) reported on base camp field data for Camp Bondsteel, Kosovo—a relatively large complex that was built up over several years. Camp Bondsteel was located in a non-arid region where water supplies are not scarce. Reported water usage at Camp Bondsteel ranged from 26 to 52 gpcd.

Mejia (2010) reported on field data from Kabul, Afghanistan, which were based on water issued to approximately 17,000 PAX during July and August. Based on the e-mail received, the water usage was only 1 gpcd. This is likely a statistical outlier based on incomplete data since the quantity of 1 gpcd is less than the minimum required for personal consumption alone.

A Strategic Environmental Research and Development Program (SERDP) funded study on forward operating bases (Noblis 2010) reported a range of water usage from 22–55 gpcd. The report recommended calculating water requirements at 35 gpcd.

Finally, field data reported by Rybacki and Bruen (2010) for two operations analyzed by the Center for Army Analysis: (1) the Total Army Analysis [TAA] 15 MCO-1 Swiftly Defeat [SD] Campaign, and (2) the TAA-17 IR-1 Campaign. This report expressed water usage in pounds, and (rarely for recent data) also included water usage per person. For Swiftly Defeat, they reported 98 lb/person, or about 11.7 gal per person. For the IR-1 Campaign, they reported 69 lb/person, or about 8.3 gal per person. Both quantities are slightly lower than the CASCOM recommendation, but are reasonably close to the requirement of 13 gal/day. Also, both reported quantities were well above the minimum human consumption requirements for arid regions shown in Figure 1.

4 Contingency Base Camp Visits

A member of the study team traveled to Afghanistan in January 2011 and visited contingency base camps to conduct staff interviews, observe operations, and collect usage data. At all bases visited, water was pumped from deep wells inside the base camp perimeter, and was treated through either granular activated carbon (GAC) or a Reverse Osmosis Water Purification Unit (ROWPU), and then chlorinated. All observed bases used bottled water exclusively for drinking and teeth brushing, regardless of whether bulk potable water was available. In calculating demand, it was assumed that each soldier consumed 1 gal/day in bottled water. Base camps varied in size, maturity, mission, and levels of service.

A number of variables determine total water demand at a base camp. One significant variable is the level of facility construction activity. Large volumes of water can be used for soil compaction, concrete production, and dust suppression. Although not specifically measured, at bases where construction activity was high, there appeared to be a higher water demand. Laundry operations also create a significant demand. Whereas most urban base camps use private off-base laundry services (Phoenix, New Kabul Compound [NKC]), large remote bases (e.g., Camp Leatherneck) typically require an on-site laundry operation. Water production and demand data are summarized below.

1.5 Camp Phoenix

Camp Phoenix is an urban base camp of 4000 personnel, and is part of the Kabul Base Cluster. Water was pumped from five on-site wells and processed at an on-site treatment plant. Potable water was distributed to the DFAC, showers, and latrines, but soldiers still used bottled water for drinking and teeth brushing. The base Directorate of Public Works (DPW) reported a demand of 100 Kgal/day, which translates to a per capita demand of 25 gpcd, or 26 gpcd including bottled water demand. This base camp had no on-site laundry and had a moderate level of construction activity. Figures 2 and 3, respectively, show the Phoenix water plant and a sign for the facility supplied with potable water.

Figure 2. Phoenix water plant.

Figure 3. Sign on Phoenix latrine-shower-sink unit.

1.6 New Kabul Compound (NKC)

NKC is an urban base camp with a population of 1000 that is part of the Kabul Base Cluster. Water at this location was pumped from on-site wells and processed at an on-site treatment plant. Treated water, although not declared "potable," was distributed to the DFAC, showers, and latrines. The base Mayor Cell reported a production of 25 Kgal/day. This translates to a per capita demand of 25 to 26 gpcd when bottled water demand is added. This base camp had no on-site laundry and had a low level of construction activity.

1.7 Forward Operating Base (FOB) Salerno

Salerno is a remote base near the Pakistani border with a population of 5600. Water was pumped from five on-site wells and processed at an on-site treatment plant. Treated water, although not declared "potable," was distributed to the DFAC, showers, and latrines. The LOGCAP contractor water plant personnel reported a demand of 140 Kgal/day. This translates to a per capita demand of 25 to 26 gpcd, including bottled water demand. This base camp had a moderate level of construction activity.

A significant future impact to water demand at Salerno is the impending replacement of the water treatment system of GAC and micron filtration with a ROWPU system. The current system is reported to achieve potable water standards, therefore the ROWPU will not improve water quality. ROWPU treatment, while effective at treating water is dramatically less efficient than standard treatment. Figures 4 and 5, respectively, show a Salerno well house, and the GAC vessel at the Salerno water plant.

Figure 4. Salerno well house.

Figure 5. GAC at Salerno water plant.

1.8 Camp Leatherneck

Camp Leatherneck is a remote base in southwest Afghanistan with a population of 20,000. Water was pumped from on-site wells and processed at an on-site treatment plant. Treated water, although not declared "potable," was distributed to the DFAC and a majority of showers, and latrines. The LOGCAP contractor data report showed production of 528 Kgal/day for potable water and 140 Kgal/day of non-potable. This translates to a total per capita demand of 33 gpcd, or 34 gpcd when bottled water demand is added. This base camp had on-site laundry and a high level of construction activity.

Camp Leatherneck is a well designed base camp that incorporates graywater capture systems from the latrine-shower-sink units. This water can then be used for treatment/reuse in showers and laundry, construction or dust abatement. This practice should be incorporated into all contingency base camps where feasible. Figures 6 and 7 show Camp Leatherneck graywater storage and new water storage tanks, respectively.

1.9 FOB Lindsay

FOB Lindsay is a small base near the large North Atlantic Treaty Organization (NATO) base of Kandahar Airfield in southwest Afghanistan. This camp has a population of 1200. Water was pumped from on-site wells, and super chlorinated at the source. A bulk of this water was distributed to showers and latrines. The rest of the chlorinated water was processed through an on-site ROWPU to supply the DFAC. The Mayor Cell personnel reported production of 4.5 Kgal/day potable water and 30 Kgal/day of non-potable water. This translates to a total per capita demand of 28.8 gpcd, or 29.8 gpcd when bottled water demand is added. This base camp had no on-site laundry and a moderate level of construction activity. Figures 8 and 9 show FOB Lindsay well point and ROWPU, respectively.

Figure 6. Camp Leatherneck graywater storage.

Figure 7. Camp Leatherneck new water storage tanks.

Figure 8. FOB Lindsay well point.

Figure 9. FOB Lindsay Reverse Osmosis Water Purification Unit (ROWPU).

1.10 Observed demand summary

The consolidated data for water demand in Afghanistan in 2011 (Table 2) show that water usage at FOBs ranges from 26 to 34 gpcd. A weighted average calculated by combining total production across the five base camps and dividing by the combined total population, yields a demand of 31.4 gpcd. The median demand is 26 gpcd.

Table 2. Water demand in Afghanistan in 2011.

Camp	Population	Portable Production (Kgal/day)	Non-Potable Production (Kgal/day)	Bottled Water Demand (gpcd)	Total Production (Kgal/day) (Includes bottled water	Total Demand (gpcd) (Total production/population)	Laundry	Construction Activity	Data Source
Phoenix	4,000	100	0	1	104	26.0	No	Moderate	Interview with DPW
New Kabul Compound	1,000	25	0	1	26	26.0	No	Low	Interview with Mayor
Salerno	5,600	140	0	1	145.6	26.0	Unk.	Moderate	Interview with water plant personnel
Camp Leatherneck	20,000	528	140	1	688	34.4	Yes	High	LOGCAP data report
Lindsay	1,200	4.5	30	1	35.7	29.8	No	High	Interview with Mayor
Combined/ Weighted	31,800				999.3	31.4			

5 General Observations of Base Camps

1.11 Afghanistan base camps

5.1.1 Sustain

All observed base camps were able to produce high quality raw water from deep wells within the base camp perimeters. This water does not require a robust treatment process to achieve potable water standards. Also having wells within the perimeter increases security of water sources. As discussed above, Camp Leatherneck has implemented graywater capture systems that should lead to a decrease in production requirements. A review of available master plans shows that other bases also use graywater capture. Most bases that have developed beyond austere conditions use a central water treatment plant capable of achieving potable water standards. This is a positive step toward dramatically reducing the use of bottled water in theater.

5.1.2 Improve

All personnel continue to depend on bottled water for drinking and teeth brushing, even at bases where bulk potable water is available. Observations show that much of the bottled water is wasted, e.g., when personnel open a bottle and do not consume the entire volume, wasting as much as 20% of the bottled water. Also, the theater shows a strong preference toward the use of ROWPU systems for base camp water treatment. Because of the high quality of the source water from deep wells, standard water treatment processes would be as effective for sanitation, and much more cost effective. The ROWPU process requires 3 gal of raw water for each gallon of treated water produced (HQ USAF 2011), and requires significantly more electrical power that standard water treatment processes.

1.12 Measured usage at Continental US training FOBs

CERL personnel visited Camp Atterbury, IN and Fort Irwin, CA training FOBs to observe water usage and other utilities. Camp Atterbury is located in a non-arid location; data were collected there from June 2009 to January 2010. Of the three FOBs at Camp Atterbury, only one has a segregated water supply from which usage specific to that FOB could be measured. Fort Irwin is located in a hot arid area, but water is not trucked in and no attempt has been made to limit water usage during training. Thus, Fort Irwin is an example of an arid site with abundant water supply.

5.1.3 Camp Atterbury

Table 3 lists water usage data from Camp Atterbury, FOB III. These data are for the area of Camp Atterbury, which is supplied by a segregated water supply with a meter measuring usage. The data in Table 3 indicate that water usage ranges from 6.1 to 22.7 gpcd. Based on conversations with the staff at Camp Atterbury, this FOB does not operate full time; some personnel may commute to training from outside the FOB. Also the nature of an FOB with a transient training population does not require permanent facilities with large water requirements. Functions such as laundry and washracks are typically found in the main area of the post. Often, a training FOB receives DFAC support from main post; prepared food is brought to the FOB serving facility. When demand is averaged using the cumulative population and cumulative production, the resulting per capita water demand is 13.2 gpcd, right in line with the basic requirement for individual soldiers.

5.1.4 Fort Irwin

The data from Fort Irwin are less detailed. The main purpose of water usage analysis at Fort Irwin was the long-term stability of the water supply. Due to the desert conditions and limited recharge, Fort Irwin is "mining" water resources that are not replaced. During training, water usage as would be required during deployment is not emphasized. Estimates of water usage at Fort Irwin are 60 to 80 gpcd. Due to the lack of restrictions on water use, water usage at Fort Irwin is considered to be a statistical outlier.

1.13 Demand summary

Adding the demand figures from Camp Atterbury and Camp Bulwark yields a slightly lower weighted average demand of 28.9 gpcd. Because of the large number of variables that can affect the demand of a specific camp, a single baseline demand number cannot be completely accurate. Observed demand at Camp Atterbury, which represents an austere base camp location with few large water consumers, validates the 13 gpcd number for basic subsistence. Since most contingency camps will have several additional functions, real world data indicate that the two current planning factors (KBR – 18.4 gpcd, and EPBS – 20 gpcd) are too low. The calculated daily per capita average of 28.9 gpcd is fairly consistent with the value in the CASCOM water planning tool. Table 3 lists the combined water demand.

Table 3. Water usage data from Camp Atterbury, FOB III.

Measure	Month								Total
	Jun	Jul	August	Sep	Oct	Nov	Dec	Jan	
Gal	196,000	370,000	167,000	384,000	490,000	74,000	41,000	40,800	1,762,800
PAX	620	1,120	570	640	730	350	225	180	4,435
gpcd	10.5	11	9.8	20	22.7	7	6.1	7.6	13.2

Table 4. Combined water demand.

Camp	Population	Portable Production (Kgal/day)	Non-Potable Production (Kgal/day)	Bottled Water Demand (gpcd)	Total Production (Kgal/day) (Includes bottled water	Total Demand (gpcd) (Total production/population)	Laundry	Construction Activity
Phoenix	4,000	100	0	1	104	26.0	No	Moderate
New Kabul Compound	1,000	25	0	1	26	26.0	No	Low
Salerno	5,600	140	0	1	145.6	26.0	Unk.	Moderate
Camp Leatherneck	20,000	528	140	1	688	34.4	Yes	High
Lindsay	1,200	4.5	30	1	35.7	29.8	No	High
Atterbury	4,435	58.8	0	0	58.8	13.3	No	Low
Bulwark	1,100	22.1	0	0	22.1	20.1	No	Low
Combined/ Weighted	37,335				1,080.2	28.9		

5.2 Summary

A comparison of currently used planning factors to observed usage at base camps indicates that current demand generally falls within the range of the planning factors. Table 5 lists water demand planning factors and observed usage.

Based on the data generated from the study, planned water usage was estimated for three sizes of base camps: (1) a company of 120 PAX, (2) a battalion of 1000 PAX, and (3) a brigade of 6000 PAX. These estimates are based on CASCOM minimum planning factors, evidence-based practices (EBPs) master planning factor currently used in Afghanistan, and field observed usage at selected base camps. Note that these base camp sizes do not include contractor personnel, which can more than double the population of larger base camps. Table 6 lists the estimated water requirements by base camp size.

Table 5. Water demand planning factors and observed usage (gpcd).

Basic Sustainment			Sustainment w/Additional Functions			Observed Usage	
CASCOM	WHO	Bright Star	KBR	EPBS	CASCOM	Range	Median
13.0	13.2	13.0	18.4	20.0	34.1	13.3–34.4	26.0

Table 6. Estimated water requirements by base camp size.

		Planning Factor (gpcd)		
Unit	PAX	CASCOM 34.16	EPBS 20	Recommended 30
Company	120	4,152	2,400	3,600
Battalion	1,000	34,600	20,000	30,000
Brigade	6,000	207,600	120,000	180,000

6 Conclusions and Recommendation

To provide baseline water resource information pertaining to forward operating bases (FOBs) that can be used to optimize future deployed operations, this study determine water usage at FOBs, compared actual usage to planning factors previously developed by the Army, and estimated water requirements by base camp size:

1. Observed water usage at base camps ranged from 13.3–34.4 gpcd (Table 5).
2. A comparison of currently used planning factors to observed usage at base camps indicates that current demand generally falls within the range of the planning factors. Table 5 lists water demand planning factors and observed usage.
3. Water requirements were estimated for three base camp sizes:
   a. a company of 120 PAX
   b. a battalion of 1000 PAX
   c. a brigade of 6000 PAX.
4. Based on CASCOM minimum planning factors, evidence-based practices (EBPs) master planning factor currently used in Afghanistan, and field observed usage at selected base camps, this work recommends a base camp planning factor of 30 gpcd (Table 6).

Acronyms and Abbreviations

Term	Definition
AEPI	Army Environmental Policy Institute
AF	Air Force
AKO	Army Knowledge Online
AOR	Area of Responsibility
ARCENT	Army Forces Central Command
ASAALT	Assistant Secretary of the Army for Acquisition, Logistics, and Technology
BEEF	Base Engineer Emergency Forces
BTW	bottled water (BTW)
CAC	Common Access Card (CAC)
CASCOM	US Army Combined Arms Support Command
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CENTCOM	US Central Command
CERL	Construction Engineering Research Laboratory
CONUS	Continental United States
COP	Company Outpost
COR	Contract Officer Representative
DFAC	Dining facility
DOD	US Department of Defense
DPW	Directorate of Public Works
EBP	Evidence-Based Practice
EPBS	Expeditionary Prime BEEF [Base engineer Emergency Forces] Squadrons
ERDC	Engineer Research and Development Center
EXORD	Execution Order
FOB	forward operating base
GAC	granular activated carbon
gpcd	gallons per capita per day
HQDA	Headquarters, Department of the Army
ICDT	Integrated Capabilities Development Team
KBR	Kellogg Brown and Root
LOGCAP	Logistics Civil Augmentation Program
MANSCEN	US Army Maneuver Support Center
MHG	Marine Headquarters Group
NATO	North Atlantic Treaty Organization
NCOIC	Non-Commissioned Officer in Charge
NKC	New Kabul Compound
OMB	Office of Management and Budget
ROWPU	Reverse Osmosis Water Purification Unit
SAR	Same As Report

Term	Definition
SD	Swiftly Defeat
SERDP	Strategic Environmental Research and Development Program
SF	Standard Form
SIPRNET	Secret Internet Protocol Router [SIPR] Network
TAA	Total Army Analysis
TNT	trinitrotoluene
TR	Technical Report
TRADOC	US Army Training and Doctrine Command
US	United States
USACERL	US Army Construction Engineering Research Laboratory
USFOR-A	US Forces-Afghanistan
WHO	World Health Organization
WWW	World Wide Web
XO	Executive Officer

References

3rd Army (2009), "Central Coalition Forces Land Component Command, Army Forces Central Command (ARCENT) Staff Estimate, Afghan Planning," 30 Nov 09

877th Expeditionary Prime BEEF [Base engineer Emergency Forces] Squadrons (EPBS). November 2010. FOB Shindand Base Camp "Master Plan Light." Shindand District, Herat Province, Afghanistan.

Bandy, J. T., E. D. Smith, R. Hubbard, B. Bandick, W. T. Matthew, G. Thomas, and M. Testa. March 1984. Bright Star 83 after action report, water management (production/consumption) and heat stress management. White paper. US Army Construction Engineering Research Laboratory (USACERL).

Bruce, Trent, MAJ. 10 January 2011. Experience as DPW OIC, Kabul Base Cluster, 2010-11. Interview by Garth Anderson, Camp Phoenix, Afghanistan.

Buchart Horn GmbH. 2004. Base camp solid waste characterization study. US Army Corps of Engineers, Europe District, DACA90-02-D-0085, DO 0028, BH Project 06200-28, December, 2004

Catanese, P. A., and S. J. Ford III. September-October 2005. Saber FLE in Iraq. Army Logistician 37(5).

Gleick, P. H. 1996. Basic water requirements for human activities: Meeting basic needs. Water International 21:83.

HQ US Air Force (USAF). 2011. Reverse osmosis water purification unit setup and operation. Air Force Handbook 10-222. Volume 9. Washington, DC: HQ USAF, http://www.e-publishing.af.mil/shared/media/epubs/afh10-222v9.pdf

Headquarters, Department of the Army (HQDA). 16 June 2008. Army Campaign Plan 2008 Execution Order (EXORD) Washington, DC: HQDA.

Kelly, Matthew CPT. 2011. Experience as Commander HHT/4/2 CAV and FOB Mayor 2010-11. Interview by Garth Anderson, FOB Lindsay, Afghanistan, 19 January 2011.

Ketchum, M. May-June 2007. Providing clean water to the Soldier. Army Logistician 39(3).

Kinnevan, K. November 2008. Challenges and water technology objectives for sustainable operations. Military Applications for Emerging Technology Workshop.

Marine Headquarters Group (MHG), Camp Leatherneck (Colonel James Flowers, RC-SW C7; Major Jim Franks, MHG XO; Captain Thano Pravong, Camp Commandant). 2011. Experience as MHG Camp Leatherneck, 2010-11. Interviews by Garth Anderson, Camp Leatherneck, Afghanistan, 22 January 11.

McCracken, Michael MAJ. 2011. Experience as TF Rakkasans Brigade Engineer, 2010-11. Interviews by Garth Anderson, FOB Salerno, Afghanistan, 17 January 2011.

Mejia, Jose R.,, SSG, NCOIC, TF 30th Med /72nd Med Det (VS). 14 January 2010. E-mail message to Stephen W. Maloney.

Murphy, M. T., E. D. Smith, R. J. Scholze, T. Bagwell, W. T. Matthew, G. J. Thomas, and R. W. Hubbard. April 1987. Bright Star 85, water operations. USACERL Special Report N-87/13. Champaign, IL: US Army Construction Engineering Research Laboratory (USACERL).

New Kabul Compound (NKC) Mayor Cell (LTC Kirk Oldre, Mayor; SGM Terry Helget, Garrison NCOIC; MAJ Tom Krull, Deputy Garrison OIC; 1LT Margaret Bendorf, ATO; 1LT Cody Byrum, COR). 2011. Experiences as Mayor Cell in New Kabul Compound, 2010-11. Interview by Garth Anderson; Kabul, Afghanistan, 11 January 2011.

Noblis. 2010. Sustainable forward operating bases, http://www.serdp.org/content/download/8524/104509/file/FOB_Report_Public.pdf

Oshiba, Edwin, COL. 2011. Experience as Commander, 577th Expeditionary PRIME BEEF Group, 2010-11. Interview by Garth Anderson, Bagram Airfield, Afghanistan, 13 January 2011.

Ouellette, Bryan K. January-February 2008. Lessons learned from a reception, staging, onward movement and integrating site. Army Logistician. 40(1).

Rybacki, Richard, and John Bruen. 14 May 2010. Liquid logistics burden. Washington, DC: US Army Logistics Innovation Agency (USALIA).

Siegel, Steve, Steve Bell, Scott Dicke, and Peter Arbuckle. August 2008. Sustain the mission project: Energy and water costing methodology and decision support tool. Final Technical Report. ADB346027. Arlington, VA: Army Environmental Policy Institute (AEPI).

US Army Training and Doctrine Command (TRADOC). November 2009. TRADOC Base Camp Functional Area Analysis. Fort Monroe, VA: TRADOC.

Wagstaff, J. 2009. Concept of support overview, Iraq theater of operations, brief concept overview of Iraqi AOR, http://www.us.army.smil.mil/suite/doc/1186122

Wiesner, Mark LTC. 2011. Experience as Base Support Group OIC (Mayor) Camp Phoenix, Afghanistan, 2010-11. Interview by Garth Anderson, Camp Phoenix, Afghanistan, 10 January 2011.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
15-09-2013	Final	

4. TITLE AND SUBTITLE
Baseline Water Demand at Forward Operating Bases

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT

6. AUTHOR(S)
H. Garth Anderson, Stephen W. Maloney, Kurt Kinnevan, Edgar D. Smith, K. James Hay, and Gary L. Gerdes

5d. PROJECT NUMBER
622784T4100

5e. TASK NUMBER

5f. WORK UNIT NUMBER
122G16

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005,
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-13-16

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Natick Soldier RD&E Center
15 Kansas St.
Natick, MA 01760-5000

10. SPONSOR/MONITOR'S ACRONYM(S)
PM-FSS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Adequate supplies of potable water are essential for the establishment and operation of contingency base camps, especially in arid environments such as those in Southwest Asia. A baseline planning factor for water demand that reflects current contingency operations is essential to properly develop theater basing strategies and prepare valid base camp master plans. To provide that baseline, this work determined water usage at FOBs (13.3—34.4 gallons per capita per day [gpcd]), compared actual usage to planning factors previously developed by the Army, and estimated water requirements by base camp size (30 gpcd).

15. SUBJECT TERMS
Army facilities, contingency base camps, forward operating bases (FOBs), potable water, water supply

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	34	